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CONTROLLABLE CONFORMAL ELECTROMAGNETIC BAND GAP ANTENNA FOR BASE STATION

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1. INTRODUCTION

This work is a French Industry and Research project, called RNRT "BIP" (see ref.[1] for a presentation) and concern three University laboratories (IETR, IEF, GEA) and two societies (France Télécom, Adventen). The purpose of the RNRT project "BIP" is to design a beam steering multi-band (GSM/DCS/UMTS) base station antenna.

Electromagnetic band gap structures are periodic structures which take their origin from optical frequencies works [2]. To design our antenna we use a new geometry of Electromagnetic Band Gap structures, a cylindrical EBG. In a previous work [3], we have shown how to characterize in transmission coefficient cylindrical periodic structures of metallic wires. These structures, associated with the EBG propriety of electronic controllability [4][5], are now used to realize a new type of beam-steering antenna. Our concept has been the object of a French patent [6].

We first interest on the characterization of cylindrical periodic structures. Then we show the effect of defects inserted in the structure. To finish we present the geometry and the simulation results (matching and radiation patterns) of a prototype.

2. CYLINDRICAL EBG STRUCTURES

Let us consider a structure composed of multiple periodic cylindrical surfaces of infinite long metallic wires, excited by an infinite long line source in its center (Fig.1).

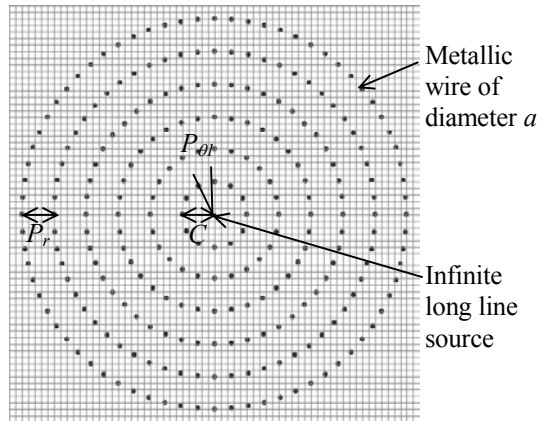


Fig.1 – Cylindrical periodic structure with six layers
 $C=P_r=40\text{mm}$, $P_{\theta l}=\pi/6$, $a=2\text{mm}$.

The structure is characterized by the number of cylindrical layers, the inner radius C , the radial period P_r , the angular periods $P_{\theta i}$ (for layer i), the transversal $P_t=P_{\theta l}*C$ (which we keep constant) and the diameter of the wires a ($P_r=C=40\text{mm}$, $P_{\theta l}=30^\circ$, $a=2\text{mm}$)

We call T the transmission coefficient of the structure obtained by calculating the transversal electric field outside the structure normalized by the electric field obtained without the structure. Fig.2 presents the $|T|$ coefficient of the structure of Fig.1. The curve shows a *band gap* (or stop band) in low frequencies and a *pass-band* in high frequencies. In the band gap, the wave going out of the structure is strongly attenuated. The structure has been designed so that the band gap contains the frequency bands of interest (GSM/DCS/UMTS). Note that the value of $|T|$ is not limited by one and that in the pass band the number of picks corresponds to the number of layers. More details in the $|T|$ coefficient (forms and values greater than one) are given in ref. [7].

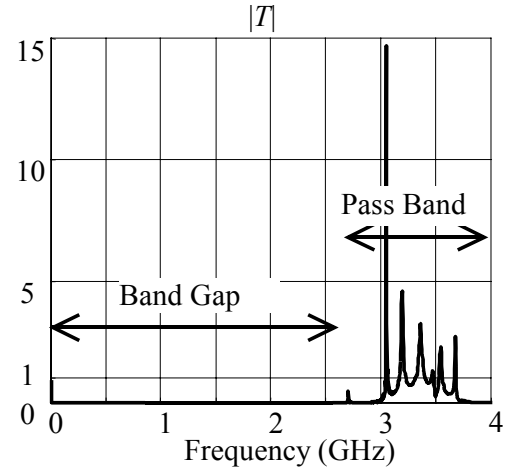


Fig.2 – Transmission coefficient $|T|$ of the structure of Fig.1 (FDTD result).

3. CYLINDRICAL EBG STRUCTURES WITH DEFECTS

Now, in the periodic cylindrical structures, some metallic wires are removed, realizing by this way defects on the periodic structures. It will be seen that the defects create "authorized" bands in the band gap: this concept takes its origin from optical frequencies works [2]. In these "authorized" bands the radiation patterns show directive diagrams in the direction of the defects.

We have studied different cylindrical structures with

defects varying the number of layers (see Fig.3). For these different structures, Fig.4 gives the radiation patterns at 2.5GHz. We can see that as the number of layers increase the diagrams become more and more directive. But the enhancement of directivity decrease as the number of layers increase.

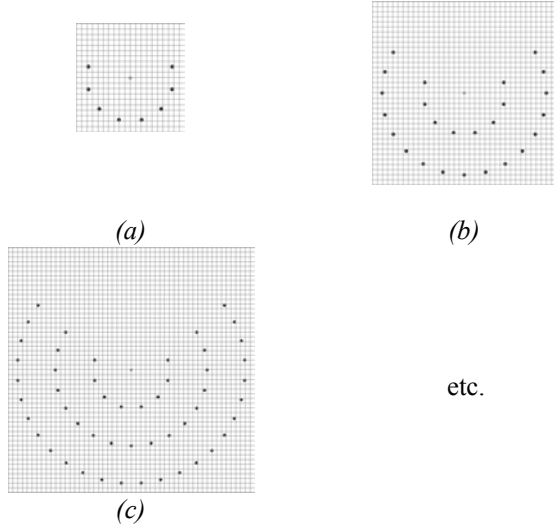


Fig.3 – Cylindrical structures with defects with (a) one, (b) two and (c) three layers, $C=40\text{mm}$, $P_{\theta l}=\pi/6$, $a=2\text{mm}$. $P_r=40\text{mm}$.

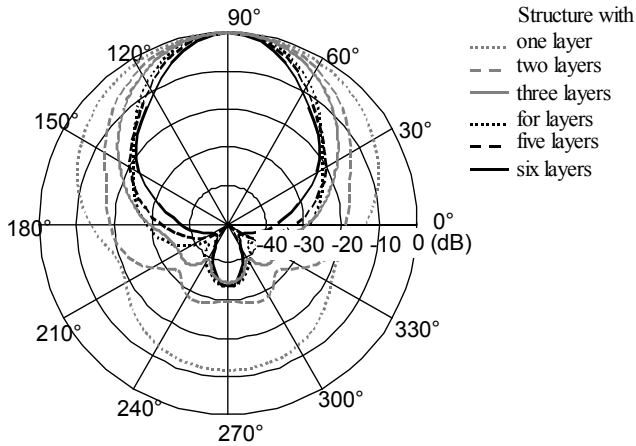


Fig.3 – Radiation patterns of different structures with multiple layers at 2.5GHz.

Let us consider now the six layers structure with defects presented in Fig.4. An observation point is put in the direction of the defects. In this point we calculate the electric field (E_{tot}) normalized by the electric field obtained without the structure (E_{inc}).

The transmission coefficient E_{tot}/E_{inc} is plotted in Fig.5. One can observe the “authorized” band created in the band gap. Fig.6 gives the radiation patterns of the structure of Fig.4 at the different frequencies of interest.

Point of
observation
↘

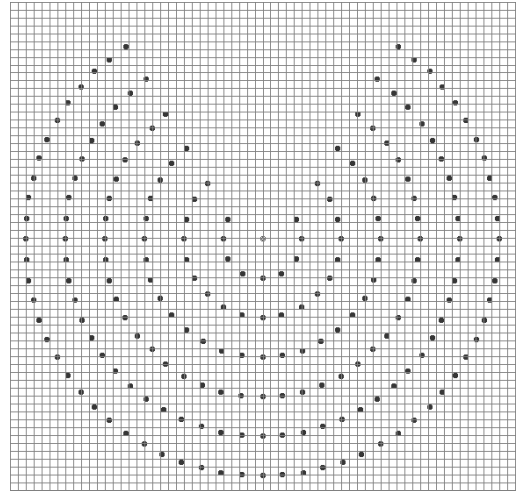


Fig.4 – Structure of Fig.1 with defects.

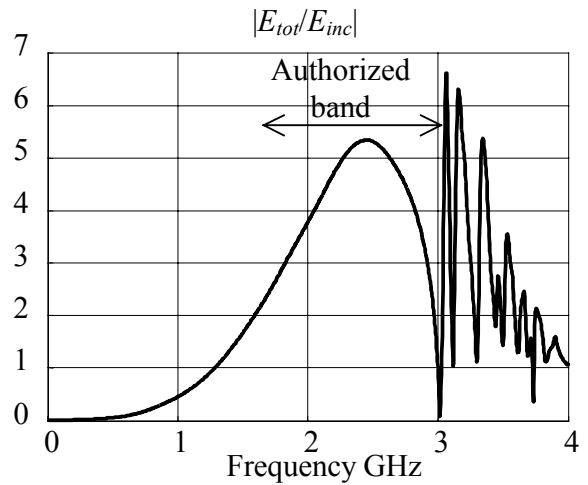


Fig.5 – Transmission coefficient of the structure of Fig.4.

There diagrams are directive at UMTS frequencies. One can see that the structure don't allow a radiation at the low GSM frequencies (0.89-0.96GHz).

To overcome this inconvenient the two first layers have been removed to obtain the structure presented in Fig.7.

The transmission coefficient of this structure (calculated by the same way than above) is plotted in Fig.8. Note that there is an authorized band in low GSM frequencies.

The radiation patterns of the structure of Fig.7 are given in Fig.9. Now the structure radiates in all the bands of interest. Note that the diagrams are fewer directives in the UMTS (along 2GHz) than those of the preceding structure. The structure of Fig.4 can be a good candidate for an antenna working only in the UMTS band.

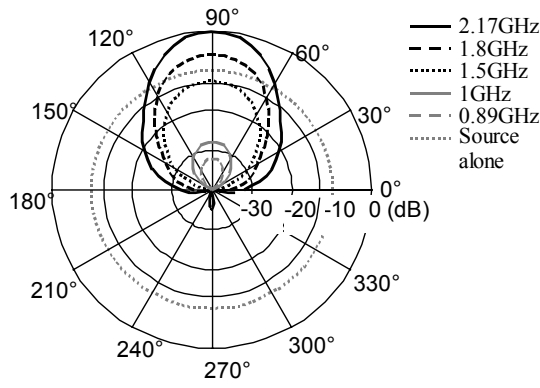


Fig.6 – Radiation pattern of the structure of Fig.4 at GSM/DCS/UMTS frequencies.

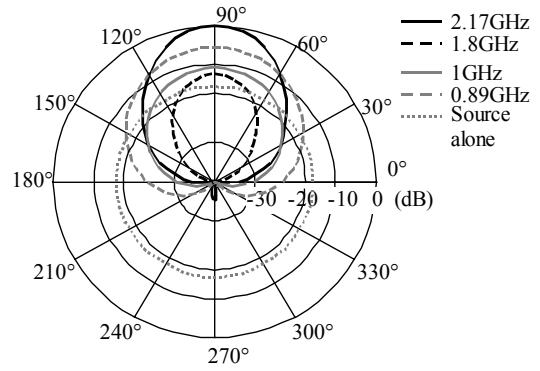


Fig.9 – Radiation pattern of the structure of Fig.7 at GSM/DCS/UMTS frequencies.

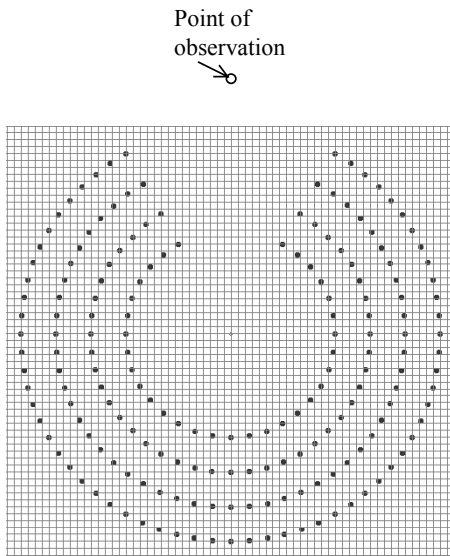


Fig.7 – Structure of Fig.4 with the first two layers removed.

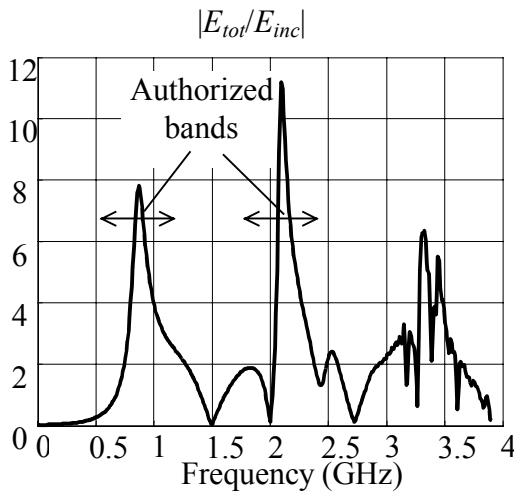


Fig.8 – Transmission coefficient of the structure of Fig.7.

4. PRINCIPLE OF THE CONTROLLABLE EBG BASE STATION ANTENNA

In practice defect wires are replaced by discontinuous wires; each wire is composed of diodes which allow passing from a continuous wire to a discontinuous wire thanks to an electric command. Fig. 10 gives the principle of the controllable base station EBG Antenna: the control by diodes allows beaming the radiation in the direction of the mobiles.

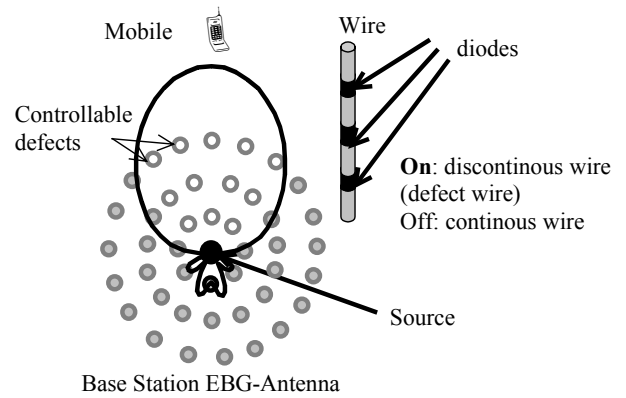


Fig.10 – Base Station controllable EBG-Antenna.

5. FIRST PROTOTYPE

To test the concept of the controllable cylindrical EBG-Antenna, a first prototype is considered. This prototype consists on only on cylindrical layer.

The excitation source is now a monopole whose parameters are given in Fig.11.

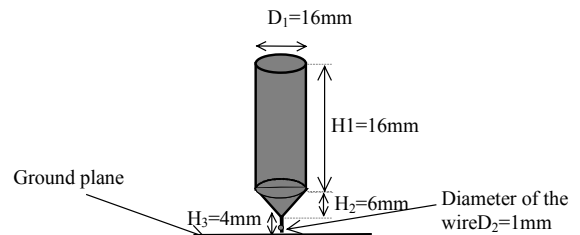


Fig.11 – Parameters of the monopole (excitation source).

Fig.12 gives the geometry of the EBG-Antenna prototype. The monopole of Fig.11 is put inside a one layer cylindrical EBG. The parameters of the periodic structure are $P_\theta = 15^\circ$, $C=100\text{mm}$ and $a=2\text{mm}$. Continuous wires have the length $L_w=166\text{mm}$. Discontinuous wires are composed of segments spaced by $s=2\text{mm}$ with the period $P_z=22\text{mm}$; these parameters have been optimized to reduce the number of discontinuities. The monopole is embedded in a foam of dielectric constant $\epsilon=2\text{mm}$. In Fig.12, we see that the EBG-antenna is matched on the first GSM Band (0.89-0.96GHz). Fig.14 and Fig.15 gives the radiation patterns at 0.94GHz, respectively, in the horizontal and the vertical planes.

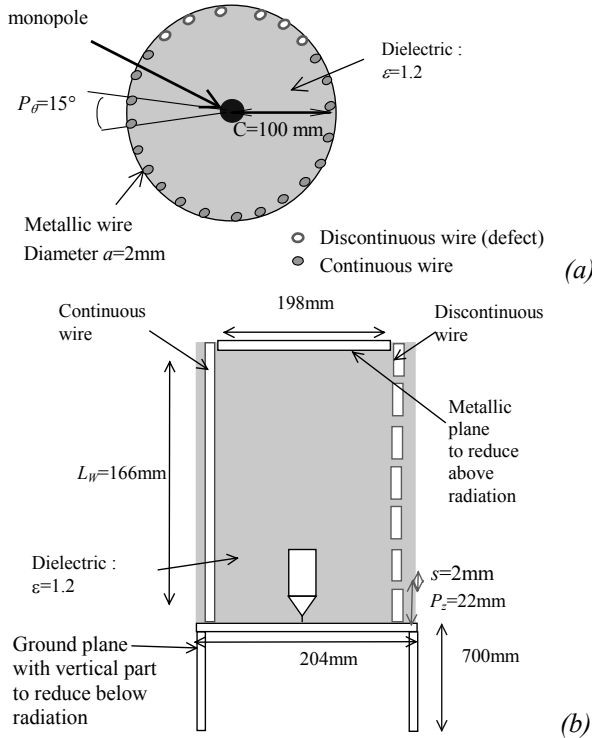


Fig.12 – Geometry and parameters of the prototype (a) horizontal view (b) vertical view.

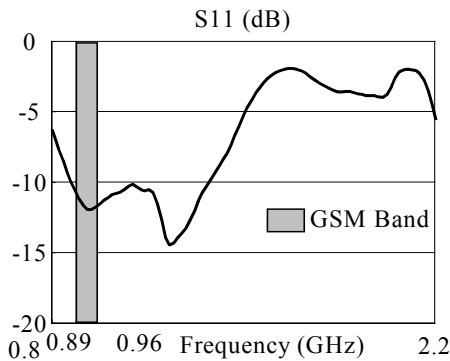


Fig.13 – Simulated matching of the antenna. The prototype is matched in the low GSM Band.

The prototype has been realized by Adventen. The measures confirm the FDTD results [1].

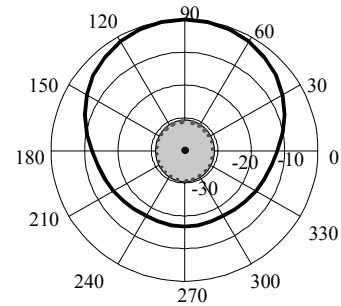


Fig.14 – Simulated radiation patterns in the H plan at 0.94GHz.

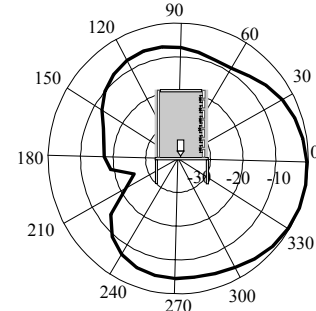


Fig.15 – Simulated radiation patterns in the E plan at 0.94GHz.

6. CONCLUSION

To conclude, we have shown in this paper a new type of beam steering antenna. We have given the results in matching and radiation pattern of a prototype working in the first GSM band. We will give later the parameters and the measures of the complete structure working in the GSM/DCS/UMTS bands.

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